DAMAGE AND MAINTENANCE OF POROUS ASPHALT PAVEMENT IN HANSHIN EXPRESSWAY

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ABSTRACT

About 85% of Hanshin Expressway is bridge structures. Recently, the porous asphalt pavements have been applied for traffic noise reduction and driver's safety in rainy days. Now the porous asphalt pavements make up about 46% of all the pavements.
In this paper, the damage of the porous asphalt pavements on the bridge decks are studied by using the inspection data of the road surface. The inspection of the pavements is operated with two levels. One is routine simple inspection. The other is 2 to 3 years periodic detail inspection. The pavement damage rate is analyzed for both regular and porous asphalt pavement. The result shows that the porous asphalt pavement has less damage rate than the dense-graded asphalt pavements. As for the damage type, the small flow ruts tend to occur more on the porous asphalt pavements than on the regular asphalt pavements. It is considered that the water which stays inside the pavements causes the ruts. In addition, the performance degradation of porous asphalt pavements due to the clogging of the voids during 8 years is surveyed. The porous asphalt pavement degradation on the bridge deck is less than that at the earthwork section. It is due to the fact that less soil has been brought on the bridge deck than at the earthwork section.

1. INTRODUCTION

Since 1962 as a public corporation, the Hanshin Expressway Company Limited (HEC) has constructed and operated urban expressways in the Kansai Metropolitan Area in Japan (See **Figure 1**). **Figure 2** shows the network of Hanshin Expressway. The first section from Minatomachi to Tosabori, was opened to traffic in 1964, and it forms a part of the current Loop Route (Route 1). The length of the expressway was only 2.3 km at that time, and only 3,000 vehicles a day used it. With a total service length of 242 km at present, the Hanshin expressway network is used by a daily average of about 900,000 vehicles or 1,300,000 people.

Except Kyoto area, the entire distance of Hanshin Expressway accounts for less than 6% of all the road area in the Hanshin Cosmopolitan area, however Hanshin Expressway burdens 15% of the total traffic and 47% of the whole freight in the region. It therefore, plays an indispensable role in the social and economic activities of the Kansai region.

Hanshin Expressway Public Corporation made a new start as the HEC on October 1, 2005, with the other public highway corporations being a part of the reformation project of the Japanese

government.

About 85% of Hanshin Expressway is bridge structures. This is the character of the urban expressway that Hanshin Expressway structures are mainly the continuing elevated structure bridges using the space over existing streets and waterway etc. because the acquisition of the expressway site is not easy in the city. Therefore, the pavements of Hanshin Expressway are mainly bridge deck pavements. We use mainly porous asphalt pavements and dense-graded asphalt pavements used polymer-modified asphalt. And we use semi-flexible pavements at near the toll gates, and usually cement concrete pavements in tunnels.

The Great Hanshin Earthquake in Kobe area in 1995 caused tremendous damage to the Hanshin expressway. The most severely affected was the Kobe Route (Route 3) in the Hyogo prefectural area. The porous asphalt pavement was applied to the earthquake restoration construction in the Kobe Route, and it was the standard on the Pavement Design Standards in 2002. Since 1995, the porous asphalt pavement has been used, and now it makes up about 46% of all the Hanshin Expressway pavements.

As for the porous asphalt pavements of the Kobe Route (Route 3), 13 years have passed. The various kinds of damages including pot holes and cracks have been seen in the road surface, and some parts of damages had replaced.

In this paper, we report the damage and maintenance of porous asphalt pavements of Hanshin Expressway.

Figure 1. Kansai metropolitan area (Hanshin region)

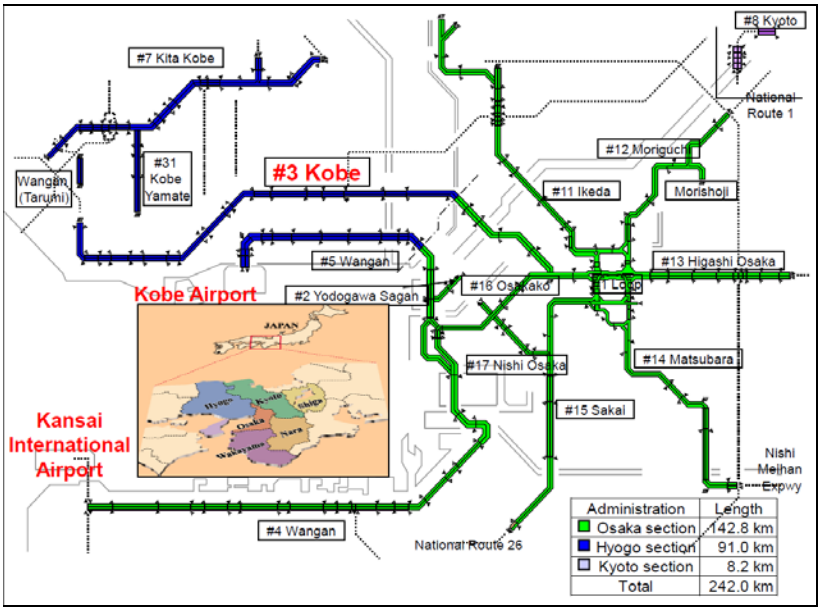

Figure 2. Hanshin Expressway network

2. THE CROSS SECTION OF THE POROUS ASPHALT PAVEMENT OF HANSHIN EXPRESSWAY

The standard cross section of bridge deck pavements of Hanshin Expressway is shown in **Figure 3**. The porous asphalt concrete is used as the surface course and the thickness of the course is 40mm. The maximum grain size of the coarse aggregate of the course is 13mm and the aggregate of abrasion loss 20% or less, the ratio of the coarse aggregate is 80%.

The mastic asphalt is used as the base course on the steel deck. The dense-graded asphalt concrete (polymer-modified asphalt) is used as the course with the waterproofing on the reinforced concrete deck. In the some steel decks, stone mastic asphalt (SMA) is used for the reasons for conditions of performance and the economy, etc.

The standard cross section of earthwork pavements is shown in **Figure 4**. The intermediate course and the binder course are set between the surface course and the base course. The porous asphalt concrete is used as the surface course, so the dense-graded asphalt concrete is used as the intermediate course for the water tightness.

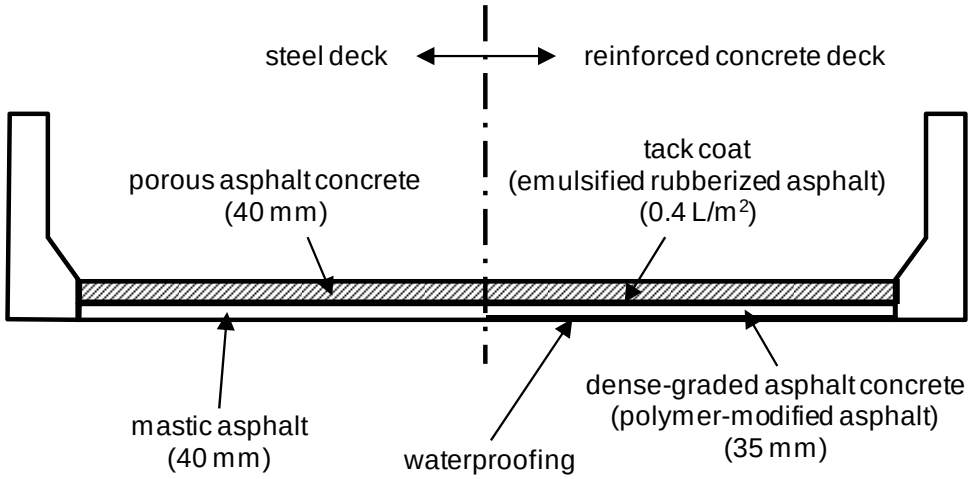

Figure 3. Standard cross section of bridge deck pavements

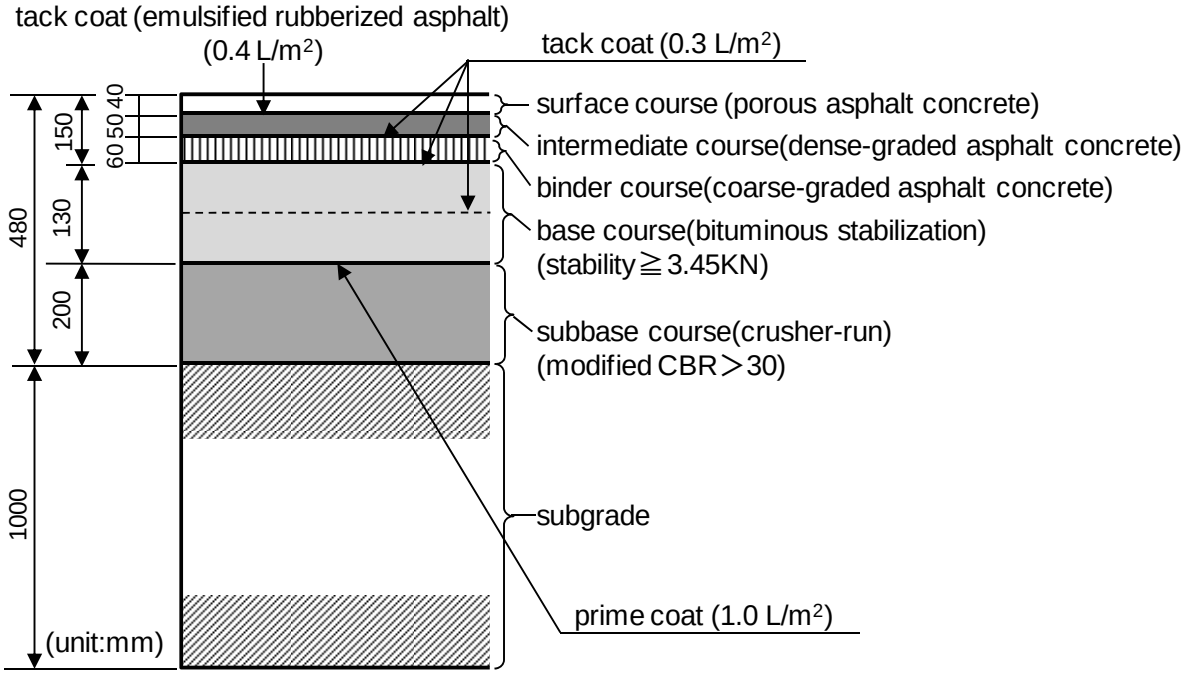

Figure 4. Standard cross section of earthwork pavements

3. THE MAINTENANCE OF THE PAVEMENT

3-1. Inspection

In Hanshin Expressway, daily road check-ups and maintenance works are keys for providing our customers and neighbor communities with safe, secure and pleasant road service and environment. Therefore, we established the inspection specification [1] and have inspected the road structures, for the purpose to understand states such as abnormality of the structure and damage and to judge the necessity or not of the measures that accepted the situation of the damage.

The inspection is divided into the initial inspection, the routine inspection, the periodic inspection, and the emergency inspection as **Table 1**, according to the purpose.

In the inspection of the pavement, we have performed the routine inspection and the periodic inspection. The method of the routine inspection is to observe the road surfaces, when we run the expressway by the patrol car. If we find the serious damage on the road surface, we get off the car and perform simple measurements of the damage, for example measuring size and depth of rutting. The method of the periodic inspection is to measure the damage of the pavements by the road surface measuring vehicle automatically every fixed period of time.

The results of the inspection are classified in 5 damage ranks as **Table 2**, and we repair the damages depending on the damage rank.

Table 1. Types of inspection

Inspection type	Main Purpose
Initial	To obtain data of new-built or rebuilt structures for their future maintenance.
Routine	A periodical patrolling or visual observation of road surface and bridges from underneath to maintain road structures in good condition at all times, thereby providing safe and smooth traffic flow and preventing damage to any third party.
Periodic	A detailed visual observation from close range and measurement of any structure Detect damage in early stage which may cause performance decline, and obtain data for repair planning.
Emergency	To check for any damage and, if any, degree of damage in the event of a disaster or accident, and obtain data for taking necessary actions.

Table 2. Damage rank and definition

Damage Rank	Definition
S	A critical deterioration level requiring an emergency repairing to prevent the danger of structural failures, accident or third party damages
A	A serious deterioration level to be repaired immediately
B	A fair deterioration level to be monitored or to be repaired if necessary
C	A minor or initial deterioration level
OK	Other than noted above

3-2. Cleaning of road surface

In order to keep the roads always in good condition, we clean the road surface regularly. The method of the road surface cleaning is the cleaning with brush type road cleaning car and the cleaning with human power on all the pavements.

We remove the sand on the entire expressway road surface with the brush type road cleaning car (See **Photo 1**), and pick up the large-size refuse by hand. Moreover, we remove the sand within the porous asphalt pavement with the vacuum type road cleaning car (See **Photo 2**) in the porous asphalt pavement section.

Photo 1. Brush type road cleaning car

Photo 2. Vacuum type road cleaning car

4. THE CURRENT SITUATION OF THE POROUS ASPHALT PAVEMENT

4-1. Damage Amount of Road Surface

In the pavement inspection of Hanshin Expressway, we inspect the road surface and keep its results by a certain traffic lane unit in span of each bridge. But, in the tunnel section and the earthwork section, a traffic lane unit regards every 100m in substitution for a traffic lane unit in the bridge span. In this paper, we report the road surface damage of the porous asphalt pavement among 32,126 traffic lanes of all kinds of the pavements.

The current porous asphalt pavement is 15,039 traffic lanes equal to 46.8% of all traffic lanes, and the dense-graded asphalt pavement is 7,416 traffic lanes equal to 23.1% of all, and the dense and gap-graded asphalt pavement is 7,691 traffic lanes equal to 23.9% of all. Here, the dense and gap-graded asphalt pavement is used in the curve section and the vicinity of the share junction department such as the entrances and the exits.

The damage incidence of the current pavement based on the routine inspection on May, 2009 is described in **Table 3**. It is found that the 7.4% of all the Hanshin Expressway pavements have been damaged. About 6.4% of all the porous asphalt pavements has been damaged, and this is less than the incidence of all the dense-graded asphalt pavement and the dense and gap-graded asphalt pavement (as follows, we call it “the dense type asphalt pavement”).

Comparing with the type of the bridge deck, it is found that the damage incidence of all the pavements on the steel deck is about four times as much as on the reinforced concrete deck. In the earthwork section, the damage incidence of all the porous asphalt pavements is about half of the dense type asphalt pavements.

Table 3. The damage incidence of the pavement

		porous asphalt pavement	dense-graded asphalt pavement	dense and gap-graded asphalt pavement	all
reinforced concrete deck	lane	12,504	5,697	5,757	24,918
	damage lane	577	316	314	1,257
	damage rate	4.6%	5.5%	5.5%	5.0%
steel deck	lane	1,915	1,153	1,289	4,531
	damage lane	342	239	274	884
	damage rate	17.9%	20.7%	21.3%	19.5%
earthwork section	lane	620	566	645	2,677
	damage lane	41	87	80	235
	damage rate	6.6%	15.4%	12.4%	8.8%
all	lane	15,039	7,416	7,691	32,126
	damage lane	960	642	668	2,376
	damage rate	6.4%	8.7%	8.7%	7.4%

4-2. Damage type of Road Surface

Figure 5 shows the damage types of each pavement and the damage types of each structure on the road surface.

At all the pavements, exfoliation including pot holes occupies nearly 60% of the whole damages, and there are a lot of damages of cracks, rutting, and longitudinal roughness. These four types of damage occupy nearly 90% of all. The ratio of exfoliation including pot holes on the porous asphalt pavements is lower than that on the dense type asphalt pavement, but the ratio of rutting on the porous asphalt pavements is about twice as much as that on the dense type asphalt pavement. It is thought that there is much flow rutting (See **Photo 3**) occurring partially on the porous asphalt pavements, because rain water stays on the base course and infiltrates onto the reinforced concrete deck at the end of the pavements.

Next, watching the situation of the occurrence according to structure, it is found that the damage of the porous asphalt pavement is more than that of the dense type asphalt pavement in the bridge. There are especially a lot of damages of cracks and stripping in the steel deck and a lot of damages of longitudinal roughness, rutting, and exfoliation including pot holes in the reinforced concrete deck in the porous asphalt pavement compared with the dense type asphalt pavement. Moreover, there are a lot of damages of longitudinal roughness and stripping in the earthwork section.

The years of service of the pavements are different in every traffic lane, so we arrange the years of service in this every traffic lane. **Figure 6** shows the relation between the years of service of the porous asphalt pavement and the damage rate. It is found that as the years of service one year increase, the damage rates around 1% increase till the seventh year, but they decrease after the seventh year. It is thought that this reason is the replacing of the pavements.

Figure 5. Damage of pavements

Photo 3. Flow rutting

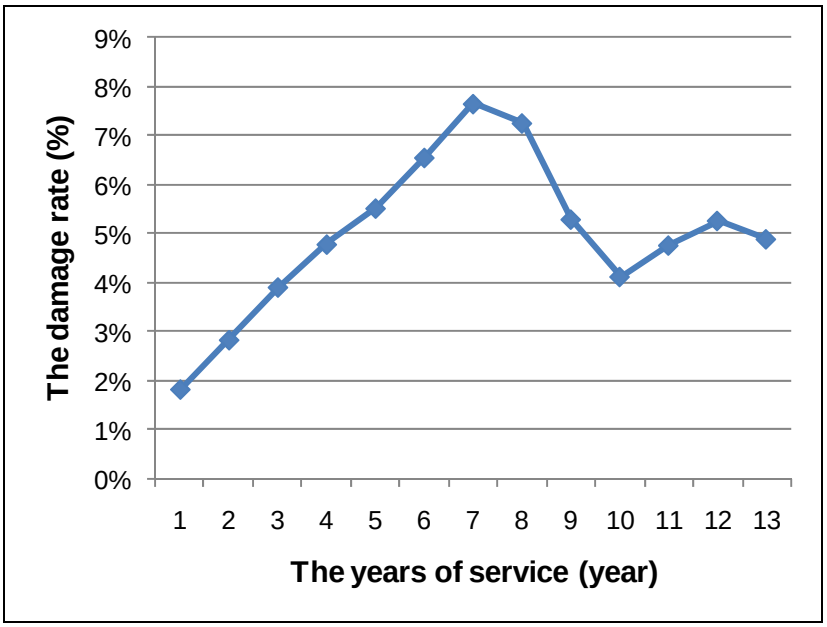

Figure 6. Relation between the years of service and the damage rate

4-3. Function of the Porous Asphalt Pavement

The porous asphalt pavements have both the drainage function and the noise reduction function. As it was the first example that executed the work at the porous asphalt pavement on a large scale in the viaduct which continued by the Kobe Route (Route 3), the follow-up inspection had done during eight years since construction.

Figure 7 shows the relation between the permeable water volume and the cumulative traffic volume at the 12 measurement points. The permeable water volume is measured by on-site test for water permeability. This test is as follows: The cylinder is put on the pavement and the water of a constant amount is put in the inside, and how many seconds it is inhaled into the road are measured. The one that acquired data is converted at 15 seconds is called the permeable water volume, and it is most often used to evaluate in Japan.

It is found that the permeable water volume falls with the cumulative traffic volume. Whereas there is the report [2] that the permeable water volume almost becomes less than 300 ml/15s in around seven or eight years on the road of earthwork section, the permeable water volume of the Kobe Route (Route 3) has kept more than 400 ml/15s in progress for eight years. It is thought that there is the influence of the traffic volume. But it is thought mainly that it is rare that the sand is carried on the road surface, as the Kobe Route (Route 3) is elevated structure. There are some places that the float water produces at the time of the rain on the shoulder of the expressway where is the end of water flow.

When the noise reduction effect of the porous asphalt pavement is compared with that of the dense type asphalt pavement, it is expected generally in frequency bands more than 1 kHz [3]. Comparing the noise reduction effect of the eight years later with that of initial in this frequency band, it is found that the noise reduction effect in the porous asphalt pavements is bigger than in the dense-graded asphalt pavements.

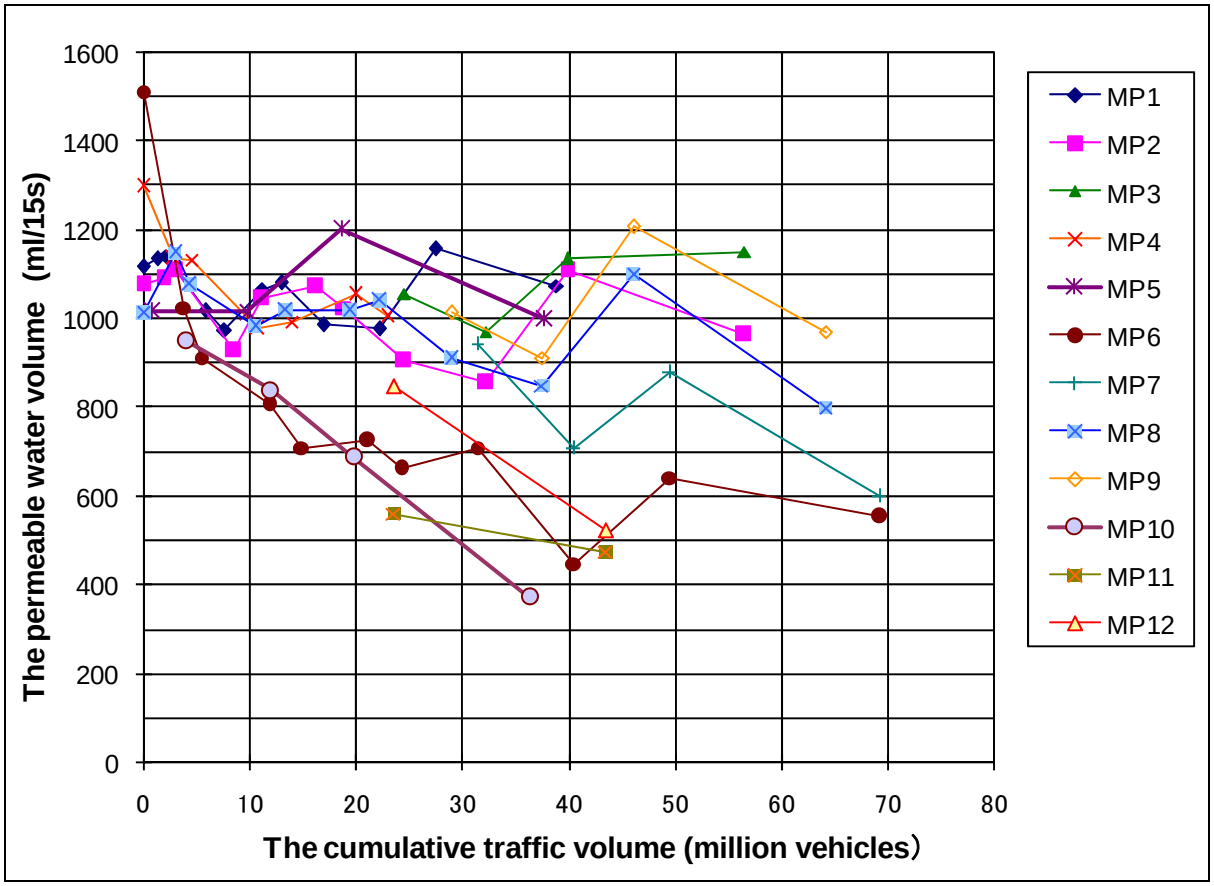

Figure 7. Relation between the cumulative traffic volume and the permeable water volume

5. THE REPAIR OF THE POROUS ASPHALT PAVEMENT

It is necessary to repair the damage pavements in order to keep the roads always in good condition, and to provide our customers and neighbor communities with safe, secure and pleasant road service and environment reducing the noise and the vibration by the vehicle running.

In case of the repair, we confirm the place, the size, and the depth, and assume the damage reason of the damage pavements from the results of the routine inspection and the periodic inspection based on the inspection specification [1]. We perform a field work to supplement the inspection results if necessary, and we decide repair necessity or not and choose a repair method. If the damage such as pot holes may affect customers, we repair it with temporary repair materials immediately, and later we reconstruct it.

The repair of the pavement is usually replacing, and the minimum unit of replacing is one traffic lane of one span as a general rule. But in case of the pot hole and sectional flow rutting we choose the method of patching, and in case of faulting by the expansion joint we choose surface coating by resinous material.

Replacing to the porous asphalt pavement from the dense type asphalt pavement, it is thought that it is desirable we replace the first lane and the second lane at the same time. But when we cannot replace at the same time, we decide to perform examination whether or not we can secure drainage.

The deterioration of the drainage function on the porous asphalt pavement of Hanshin Expressway is lower than that of the ordinary road, and the deterioration of the noise reduction function is lower, too. So the pavements are usually needed to replace for repairing the damages, before for the recovery of the drainage function and the noise reduction function.

6. CONCLUSIONS

This paper reports the damages and the repair methods of the porous asphalt pavements of Hanshin Expressway. About 6% of all the porous asphalt pavements have been damaged at the present, and there are a lot of damage of stripping including pot hole and crack. The porous asphalt pavement is at low incidence of the damage in comparison with the dense type asphalt pavement, but many of replacing pavements are within eight years old. That is, it is thought that the progress is comparatively fast when the damage occurs once though the porous asphalt pavement doesn't cause damages easily.

On the other hand, according to the results of the inspection, the damages on the porous asphalt pavements are similar to the dense type asphalt pavement, but the causes of damage are different. Therefore, it is thought that we have to evaluate the damage that occurs on the pavement road adequately. Now, we have wrestled zealously with the investigation of the damage cause including evaluation technique and the examination of the repair method.

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